

PROCESS AND APPARATUS FOR IMPROVING PHOSPHORUS REMOVAL
IN WASTE WATER TREATMENT WITHOUT CHEMICAL ADDITION

Background of the Invention

1 The present application is directed to a process for
2 the biological treatment of wastewater to remove organic
3 matter, especially while reducing the phosphorus content of
4 the effluent water without adding additional chemicals for
5 the phosphorus removal.

6 Wastewater treatment has progressed substantially in
7 the last fifty years. Early treatments utilized various
8 chemicals to rid the wastewater of organic material.
9 Subsequently, most chemical treatments have been surpassed
10 by use of microorganisms which through various processes
11 convert organic impurities in the water to various
12 combinations of carbon dioxide, methane, water and inorganic
13 nitrogen and phosphorus compounds.

14 While microorganisms are effective in reducing organic
15 content, phosphorus and nitrogen often present problems in
16 effluent water from biological processes. The present
17 application is especially directed to an improved process
18 for the removal of phosphorus from the water.

1 Phosphorus presents an eutrophic problem in that it
2 substantially enhances the growth of aquatic plant life such
3 that an influx of phosphorus may cause sufficient plant
4 growth in streams or lakes to kill fish or produce other
5 problems. Phosphorus is also a common component of human
6 or animal waste and of many household or industrial products
7 of the type that are likely to become a component of waste
8 water collected in a city's sewer system, such as soap for
9 washing clothes wherein phosphorus is used as whitener.

10 Previous processes have been developed to try to rid
11 effluent from wastewater treatment plants of phosphorus.
12 For example, one process wherein biomass and wastewater are
13 mixed in an aerated tank is generally known as the Phostrip
14 process. In the Phostrip process the biomass with some
15 uptake of phosphorus in the bacteria is separated from the
16 clarified water. The separated biomass is then subjected to
17 an anaerobic condition in a thickener or stripper. In the
18 stripper phosphorus is released by the bacteria and a
19 phosphorus rich decant is removed from the stripper and
20 treated with lime to remove the phosphorus. The biomass is
21 then returned to the aerated tank to mix with incoming
22 wastewater. This process has varying degrees of success,
23 but requires the chemical addition of lime in order to work.

1 In 1974 the inventor of the present application
2 discovered that placement of an unaerated zone or region
3 upstream of an aerobic region in an activated sludge process
4 would result in phosphorus uptake by the bacteria when in
5 the aerobic region. This process is generally referred to
6 as the Phoredox process. However, high phosphorus removal
7 with this process was not successful with all influent waste
8 water streams.

9 Subsequently, Fuhs and Chen in trying to understand the
10 mechanism of phosphorus uptake by bacteria suggested that
11 certain microorganisms (phosphate accumulating organisms),
12 while obligate aerobic organisms, could take up and store
13 certain short chain volatile fatty acids, especially acetic
14 acid and propionic acid in an anaerobic treatment region and
15 later use the fatty acids to take up phosphorus that is
16 stored in the bacteria as polyphosphate in an aerobic
17 treatment region. In theory the microorganisms store
18 polyphosphate as an energy source in the aerobic region and
19 release the energy stored in the polyphosphate later by
20 breaking high energy phosphate bonds creating surplus
21 phosphates which are released in a preceding non aerated
22 region. Thereafter, if short chain fatty acids are
23 available in an anaerobic region, the acids are stored in

1 certain bacteria as an intermediate product, such as poly- β -
2 hydroxybuterate (PHB). As the biomass passes to the aerated
3 region, the microorganisms that have stored the organic
4 acids metabolize the PHB and use the energy gained to again
5 take up phosphorus from the surrounding liquid. Within the
6 theory of this process the microorganisms will take up more
7 phosphorus in the aerobic region than is released in the
8 anaerobic region, if sufficient amounts of the short chain
9 fatty acids are available. Thus, in theory, if excess
10 biomass is wasted, then the phosphorus in the influent
11 wastewater should be wasted with the wasted biomass. If
12 insufficient fatty acids are present, then the phosphorus
13 will remain outside the biomass and will be discharged with
14 the effluent water.

15 While certain actual treatment facilities do receive
16 wastewater with such short chain fatty acids in sufficient
17 quantity to produce at least some phosphorus reduction, many
18 have little or do not have enough to remove most or at least
19 a substantial amount of the phosphorus. The shortage of
20 short chain fatty acids can be made up by addition of the
21 fatty acids from an external source, but this is a
22 comparatively expensive and undesirable chemical addition.

23 Consequently, applicant has found a need for a method

1 of biologically producing such short chain fatty acids
2 within the biological process and has found a simple and
3 surprisingly effective method and apparatus for doing so.

4

5 Summary of the Invention

6

7 A process and apparatus are provided to improve the
8 removal of phosphorus from a waste water stream without
9 requiring the addition of chemicals to achieve improved
10 phosphorus removal. In particular, in the treatment of the
11 wastewater, the water is first directed to a first anaerobic
12 region, zone or basin wherein the influent wastewater is
13 mixed with biomass containing microorganisms that has been
14 removed from previously treated wastewater and partially
15 recycled to the first anaerobic region. The biomass prior
16 to being recycled to the first anaerobic region is
17 comparatively starved for organic food in that it has not
18 been exposed to an organic food source since entering the
19 biomass recycling system. Also, the biomass prior to being
20 recycled to the first anaerobic region contains a
21 comparatively high amount of phosphorus that is available to
22 provide energy to the bacteria in the biomass. In the first
23 anaerobic region, the biomass mixes with and absorbs organic

1 food material contained in the influent wastewater. A
2 portion of the organic food material in the wastewater is
3 normally short chain volatile fatty acids, especially acetic
4 acid and propionic acid and this term is intended to include
5 intermediaries of such acids. These short chain fatty acids
6 are especially important in the process of the present
7 invention, because when these acids are metabolized in a
8 subsequent aerobic region, the fatty acids provide energy
9 needed for the biomass to uptake and store phosphorus. If
10 the fatty acids are not present in sufficient quantity then
11 the phosphorus that is contained in the incoming biomass may
12 not be taken up later by the biomass nor will the phosphorus
13 in the influent wastewater be taken up, so that the
14 phosphorus that is not later taken up will pass through with
15 the water and will be discharged with the effluent water
16 stream. Some influent wastewater streams have insufficient
17 short chain fatty acids to allow the biomass to later take
18 up the phosphorus or only enough to take up some of the
19 phosphorus. The process of the present invention allows
20 facilities treating wastewater that are deficient in short
21 chain fatty acids to achieve very good biological phosphorus
22 removal without requiring chemical addition to chemically
23 remove the phosphorus or to require the addition of fatty

1 acids from an outside source.

2 In the first anaerobic region, solids retention time is
3 such that certain microorganisms in the biomass that contain
4 phosphorus utilize the phosphorus to produce energy and in
5 so doing release at least some of the stored phosphorus into
6 the fluid within the first anaerobic region.

7 While the phosphorus is being released, a side stream
8 of the biomass-wastewater mixture (mixed liquor) is removed
9 from the first anaerobic region, preferably on a continuous
10 basis and directed to a second anaerobic region, zone or
11 basin wherein the flow rate and solids retention is slowed
12 compared to the first anaerobic region. For example, the
13 first anaerobic region may have a flow rate calculated to
14 provide a solids retention time that will in turn produce a
15 biomass concentration of 2000 to 4000 milligrams per liter,
16 whereas the biomass concentration in the second anaerobic
17 region is preferably in the range from 7000 to 25,000
18 milligrams per liter. Preferably, the side stream enters
19 near the bottom of the second anaerobic region and flows
20 upwardly therethrough.

21 In the second anaerobic region, it is preferably
22 desirable to have the flow rate sufficiently slow to allow a
23 biomass blanket to form on the bottom of the region and to

1 fill the second anaerobic region to the level where the
2 fluid therefrom flows out of the second anaerobic region.
3 The flow from the second anaerobic region is returned to the
4 first anaerobic region, although the flow from the second
5 anaerobic region is returnable to near the same locations
6 from which it was withdrawn from the first anaerobic region
7 or, for example, the return flow can be returned to a
8 downstream location in the first anaerobic region so that
9 the short chain fatty acids produced in the second anaerobic
10 region is mixed with the biomass before entering an aerobic
11 region.

12 In the second anaerobic region, certain microorganisms in
13 the biomass in an anaerobic process convert or ferment
14 longer chained organic compounds in the wastewater to the
15 desired very short chain volatile fatty acids including,
16 especially acetic acid and propionic acid and related
17 compounds. While it is desirable for the biomass to build
18 up in the second anaerobic region, it is also desirable for
19 the short chain fatty acids to flow through and be washed or
20 carried by the outflow from the second anaerobic region to
21 the first anaerobic region.

22 When the short chain fatty acids are received in the
23 first anaerobic region, the microorganisms in the first

1 anaerobic region that have used the phosphorus therein to
2 produce energy and that have expelled at least a portion of
3 the phosphorus, take up, acquire or absorb the short chain
4 fatty acids that were produced in the second anaerobic
5 region without metabolizing the fatty acids in an oxygenated
6 process.

7 Subsequently, the mixed liquor from the first anaerobic
8 region is flow transferred downstream to an anoxic region
9 and, thereafter, to an oxic or aerobic region. In the oxic
10 region, the short chain fatty acids that were acquired by
11 the microorganism or stored therein or therewith, are
12 metabolized utilizing oxygen to produce energy. After the
13 metabolism of the short chain fatty acids, it is
14 theorized that the associated microorganisms then have
15 sufficient energy to again take up phosphorus from the mixed
16 liquor and store this phosphorus in a form having high
17 energy phosphate bonds. The amount of phosphorus taken up
18 by the biomass in the oxic region, provided that there is
19 sufficient short chain fatty acids present in the first
20 anaerobic region, is greater than was released in the first
21 and second anaerobic regions, so not only is the phosphorus
22 that was released in the anaerobic regions reacquired, but
23 also a major portion or all of the phosphorus that was

1 contained in the incoming wastewater is taken up by the
2 biomass. This is possible partly because the quantity of
3 the biomass has grown and is greater by the time the biomass
4 flows downstream from the anaerobic regions to the oxic
5 region as compared to the biomass that was recycled to the
6 first anaerobic region, but more so because of the energy
7 gain in the biomass that subsequently results from
8 sufficient short chain fatty acids being present in the
9 anaerobic region in accordance with the present invention.

10 Some of the effluent from the oxic region may be
11 recycled to the anoxic region. The remainder of the
12 effluent of the oxic region flows downstream to a clarifier
13 wherein flow rates are slowed and the biomass is allowed to
14 settle due to gravity in a quiescent region and become
15 separated from clarified water. A portion of the biomass
16 from the clarifier is wasted to storage or transferred to
17 another process for further processing and the remainder is
18 preferably recycled to the first anaerobic region.

19 Preferably, the recycled biomass flows first through a
20 preanoxic region and thereafter to the first anaerobic
21 region to remove nitrates in the biomass. The clarified
22 water with a consequent comparatively low or no phosphorus
23 content is discharged from the process.

1 It is also noted that certain wastewater includes
2 nitrogen compounds that are present in the influent or that
3 are formed by operation of the microorganisms on organic
4 material containing nitrogen. The present process is
5 cooperatively usable with conventional nitrogen removal
6 stages or processes.

7

8 Objects and Advantages of the Invention

9

10 Therefore, the objects of the present invention are to
11 provide an apparatus for use in waste water treatment for
12 operably removing phosphorus from influent waste water being
13 treated and that has insufficient short chain fatty acids to
14 support substantial phosphorus removal utilizing
15 microorganisms and without requiring chemical addition for
16 the phosphorus removal; to provide such an apparatus having
17 a first anaerobic region for mixing influent waste water and
18 recycled biomass to form a mixed liquor and a second
19 anaerobic region with associated flow conduits and pumps or
20 the like to allow a portion of the mixed liquor to be
21 transferred from the first to the second anaerobic region
22 wherein the solids retention rate is increased in comparison
23 to the first anaerobic region and wherein fermentation

1 processes produce short chain volatile organic acids which
2 are thereafter returned to the first anaerobic region for
3 uptake by microorganisms therein; to provide such an
4 apparatus having an oxic region flow located downstream from
5 the first anaerobic region for aerobically treating the
6 mixed liquor so that certain microorganisms that have stored
7 short chain fatty acids as PHB, metabolize the PHB and,
8 thereafter, uptake phosphorus; to provide such an apparatus
9 having a settling region for separating biomass from
10 clarified water downstream of the oxic region and from which
11 a portion of the separated biomass is wasted and the
12 remainder is returned to the first anaerobic region; to
13 provide such an apparatus including structure for operably
14 reducing nitrogen containing compounds in the waste water
15 that acts cooperatively with the remainder of the apparatus;
16 to provide a method to be used in conjunction with the above
17 noted apparatus that allows removal of all or a large
18 portion of phosphorus from a waste water stream that has
19 insufficient short chain fatty acids to provide for such
20 removal and wherein the process does not require addition of
21 chemicals such as lime, metal salts or short chain fatty
22 acids from an external source in order to achieve relatively
23 high phosphorus removal so that effluent water is relatively

1 low in phosphorus content; and to provide such an apparatus
2 and method which are environmentally beneficial, are easy to
3 use for their intended purpose, are comparatively
4 inexpensive relative to other processes that remove
5 phosphorus and are especially well adapted for the intended
6 use thereof.

7 Other objects and advantages of this invention will
8 become apparent from the following description taken in
9 conjunction with the accompanying drawings wherein are set
10 forth, by way of illustration and example, certain
11 embodiments of this invention.

12 The drawings constitute a part of this specification
13 and include exemplary embodiments of the present invention
14 and illustrate various objects and features thereof.

15

16 Brief Description of the Drawings

17

18 Fig. 1 is a schematic drawing of a waste water
19 treatment apparatus, especially adapted for the removal of
20 phosphorus from the waste water in accordance with the
21 present invention.

22

1

2 Detailed Description of the Invention

3

4 As required, detailed embodiments of the present
5 invention are disclosed herein; however, it is to be
6 understood that the disclosed embodiments are merely
7 exemplary of the invention, which may be embodied in various
8 forms. Therefore, specific structural and functional
9 details disclosed herein are not to be interpreted as
10 limiting, but merely as a basis for the claims and as a
11 representative basis for teaching one skilled in the art to
12 variously employ the present invention in virtually any
13 appropriately detailed structure.

14 The reference numeral 1 generally designates a waste
15 water treatment facility. Waste water from city collection
16 sewers, industrial sewers or other sources of wastewater
17 including organic material and phosphorus containing
18 compounds, is collected or fed directly into the facility 1
19 from a waste water influent region generally identified by
20 the reference numeral 4. Effluent clarified water is
21 discharged from the facility 1 to a discharge region
22 generally identified by the reference numeral 5. The
23 discharge region 5 may be a holding tank or the clarified

1 water is preferably discharged to a stream, lake or the
2 like.

3 A first anaerobic basin, tank, zone or region 10 is
4 provided to preferably receive all of the influent
5 wastewater from the region 4 through flow conduit 6.
6 However, in certain wastewater treatment processes a portion
7 of the influent wastewater may be directed to other regions
8 for cooperate treatments or for alternative reasons. Also
9 preferably, the flow of wastewater into the region 10 is
10 continuous and the first anaerobic region 10 is constructed
11 such that the influent wastewater generally enters the first
12 anaerobic region 10 on one side and flows to the other side.
13 Alternatively, or in addition, it is foreseen that the
14 influent wastewater may enter from the top or bottom and
15 exit the opposite or any alternative flow configuration to
16 provide a pass through flow pattern. The anaerobic region
17 10 is sized to handle an expected average volume of influent
18 wastewater and this in combination with the flow path allows
19 design of the first anaerobic region 10 such that the
20 influent wastewater flows through the first anaerobic region
21 with a preselected calculated and preferred solids residence
22 time therein. For example, a preferred solids retention for
23 the first anaerobic region 10 is between 2000 and 4000

1 milligrams per liter of biomass solids, although it is
2 foreseen that this may be varied according to site and
3 operational circumstances. a hydraulic retention time
4 within the first anaerobic region 10 is preferably between
5 about 0.5 and 2.0 hours. The anaerobic region 10 (as with
6 the other regions discussed herein) may be clearly defined
7 by the structure such as a tank or basin or may be simply a
8 part of a flow channel through which the water flows and
9 wherein different regions are defined by the process that
10 occurs in the regions. Likewise, conduits may be specific
11 pipes or other flow directing structure such as overflow
12 weirs and the like.

13 In the anaerobic region 10, the waste water is mixed
14 with recycled biomass which results from processing which
15 will be discussed further below, so as to form a mixed
16 liquor of living biomass and waste water to be treated. The
17 anaerobic region 10 does not have added oxygen and is
18 preferably entirely free of nitrates or is sufficiently
19 lacking in oxygen that bacteria in the biomass can not take
20 in sufficient oxygen to significantly perform oxygenated
21 metabolic processes.

22 The biomass that is recycled to the first anaerobic
23 region 10 is comparatively starved for organic food, such as

1 is found in the wastewater. This biomass also includes a
2 wide variety of microorganisms at least some of which are
3 capable of fermenting organic material in the absence of
4 oxygen and some of which are capable of metabolizing organic
5 materials to carbon dioxide and water in the presence of
6 oxygen. The biomass specifically includes microorganisms,
7 such as *Acinetobacter* spp that are phosphate accumulating
8 organisms. The phosphate accumulating organisms while in
9 the first anaerobic region 10 utilize energy stored in
10 phosphorus bonds within the organism phosphorus compounds
11 therein to produce energy in the absence of oxygen and
12 subsequently both release excess resulting phosphates into
13 the waste water and absorb volatile short chain fatty or
14 organic acids (including acetic and propionic acid), if such
15 acids and related compounds are present in the water. The
16 organic acids are believed in theory to be temporarily taken
17 up within the microorganisms while in the first anaerobic
18 region 10.

19 A portion of the mixed liquor is removed from the
20 anaerobic region 10 and transferred to a second anaerobic
21 region 12 that is also referred to by the term "anpref"
22 region, because the second anaerobic region 12 is maintained
23 under anaerobic conditions and functions as a fermenter.

1 Flow passes from the first anaerobic region 10 to the
2 second anaerobic region 12 through a conduit 14 and is
3 driven and controlled by a pump 15. Flow returns from the
4 second anaerobic region 12 to the first anaerobic region 10
5 through a conduit 16. Preferably, the flow in the second
6 anaerobic region 12 enters near the bottom and exits near
7 the top thereof. Furthermore, the second anaerobic region
8 12 is sized and the flow rate thereinto is selected so that
9 flow through the second anaerobic region 12 is comparatively
10 slow and solids retention time (SRT) is comparatively high
11 compared to the first anaerobic region 10, such that biomass
12 collects therein and forms a blanket that rests on the bottom
13 of the second anaerobic region that preferably fills the
14 second anaerobic region 12. Normally the blanket will fill
15 the second anaerobic region 12 to overflowing.

16 Preferably, the flow rate through the second anaerobic
17 region 12 is selected and the second anaerobic region 12 is
18 sized so that the concentration of the biomass is between
19 7,000 and 25,000 milligrams per liter therein. Because of
20 the substantially oxygen free and fermenting conditions in
21 the second anaerobic region 12, certain and various organic
22 compounds found in the wastewater are reduced to simple and
23 relatively short chain fatty acids (especially acetic acid

1 and propionic acid and intermediaries thereof). The short
2 chain fatty acids are generally volatile and are more easily
3 "washed" or urged through the anaerobic region 12 in
4 comparison to the larger and entangled microorganisms in the
5 biomass therein by the comparatively slow flow rate through
6 the second anaerobic region 12, so as to wash the short
7 chain fatty acids over into the first anaerobic region 10
8 through the conduit 16. The conduit 16 can be provided with
9 multiple outlets or other mixing devices to improve
10 disbursement of the fatty acids within the wastewater in the
11 first anaerobic region 10.

12 It is theorized in accordance with the invention that
13 the microorganisms that have utilized the energy from
14 phosphorus bonds and discharged the phosphorus in the
15 anaerobic regions, then take up the short chain fatty acids
16 in the anaerobic regions and may store such for later use,
17 sometimes as intermediate products especially poly- β -hydroxy
18 butyrate (PHB).

19 While the second anaerobic region 12 is depicted and
20 described as receiving and discharging through conduits, it
21 is foreseen that the flow could be directed by or through
22 various types of structures or overflows. Furthermore,
23 while a pump is shown in the illustrated embodiment to urge

1 flow through the second anaerobic region 12, the second
2 anaerobic region 12 could be below, level with or above the
3 first anaerobic region 10 so that gravity can be used in
4 certain instances to direct flow. Still furthermore, flow
5 can be urged by other types of well known devices that
6 perform the equivalent function.

7 In many waste water treatment facilities of the type
8 described herein flow rates are such that the concentration
9 of biomass in the first anaerobic region 10 is on the order
10 of from 2000 to 4000 milligrams per liter, although as noted
11 above variation outside this range occurs at certain
12 locations. Preferably, also as noted before the biomass
13 concentration in the second anaerobic region 12 is within a
14 range from 7000 to 25,000 milligrams per liter. This
15 increased concentration indicates that the solids retention
16 time of the second anaerobic region 12 is greater in
17 comparison to the first anaerobic region 10.

18 It is foreseen under the invention that alternative
19 systems may be employed to create an anaerobic region
20 wherein biomass is located in such a manner that increased
21 fermentation will occur due to biological activity and that
22 very short chain fatty acids will be produced prior to
23 passage of mixed liquor into an anoxic or aerobic region.

1 In this manner, the fatty acids cooperate with certain
2 microorganisms to release phosphorus and take up the fatty
3 acids in the anaerobic region, such that a rebound effect
4 will occur at a downstream location in the presence of
5 oxygen where the microorganisms will respire and metabolize
6 organic material using oxygen therein and thereafter take up
7 phosphorus from the surrounding mixed liquor and store the
8 phosphorus with high energy within the cells of certain
9 microorganisms in the biomass. It is foreseen that in some
10 instances, the second anaerobic region could have a low
11 level of organic food and given sufficient time that the
12 biomass itself provides the food source.

13 It is also foreseen that the second anaerobic region 12
14 may be fitted with a mixer that would not be utilized during
15 normal operation but which may be operated from time to time
16 to reposition biomass therein. A pump could also be used
17 for this purpose by directing circulating flow into multiple
18 locations near the bottom of the second anaerobic region 12.

19 It is further foreseen that first anaerobic region 10
20 may also be divided into subregions with the flow to the
21 second anaerobic region 12 coming from a different subregion
22 than the subregion receiving return flow.

23 Downstream of the second anaerobic region 12 is an

1 anoxic region 18 joined to the first anaerobic region 10 by
2 a conduit or flow channel 20. Operably, the anoxic region
3 18 is utilized in a well known and conventional manner to
4 remove nitrates from the mixed liquor therein.

5 The mixed liquor is subsequently directed from the
6 anoxic region 18 to an aerobic region 22 through a conduit
7 or flow channel 23. In the illustrated embodiment, the
8 aerobic region includes five oxic or aerobic subregions 25
9 to 29. It is foreseen that the number of oxic regions may
10 vary greatly in accordance with the needs of the particular
11 site. The aerobic region 22 includes mixers and is operated
12 in a well known manner so as to inject oxygen by sparging
13 oxygen or air into the liquor, by spraying liquor into the
14 air, or the like, so that oxygen or air including oxygen
15 enters the aerobic region 22 while mixed liquor in the
16 aerobic region 22 is being mixed. A portion of the mixed
17 liquor exiting the aerobic region 22 is preferably returned
18 to the anoxic region 18 through conduit or flow path 33
19 under control of pump 34. For example, preferably between
20 50% and 60% of the outflow of the region 22 may be returned
21 to the region 18 so that any nitrates formed in the aerobic
22 region 22 may be reduced in the anoxic region 18. the
23 anoxic region 18 is mixed but not aerated.

1 In the aerobic region 22, certain of the microorganisms
2 in the biomass therein take up oxygen through respiration
3 and convert organic material to carbon dioxide and water.
4 Also, certain of the microorganisms in the biomass take up
5 phosphorus from the surrounding liquor. Because the biomass
6 grows between recycle and the return thereof to the aerobic
7 region 22, but much more importantly, because the organisms
8 taking up phosphorus have sufficient stored food from the
9 short chain fatty acids in the form of PHB absorbed in the
10 first anaerobic region 10, the biomass and, in particular,
11 the phosphorus accumulating organism in the biomass in the
12 aerobic region 22 takes up more phosphorus than is released
13 in the anaerobic regions 10 and 12 provided that the short
14 chain fatty acids are available in the first anaerobic
15 region 10. Thus, the microorganisms in aerobic region 22
16 preferably take up what was released in all anaerobic
17 regions plus up to 99% of all of the phosphorus coming into
18 the facility 1 with the wastewater influent.

19 Discharge from the region 22 is directed through
20 conduit or flow channel 35 to a clarifier 36. The clarifier
21 36 is not mixed and flow rates are sufficiently slow to
22 allow the biomass to become quiescent and settle to the
23 bottom of the clarifier 36 and clarified water to raise to

1 the top. The clarified water is directed through a channel
2 40 to the clarified water discharge region 5.

3 The biomass in the collected solids blanket at the
4 bottom of the clarifier 36 is directed to a conduit or flow
5 channel 43 which bifurcates into a wasted or sludge stream
6 to wasted biomass storage 45 and a recycle biomass stream 46
7 and is urged therethrough by a pump 47. The amount of
8 biomass wasted each day is approximately equal to the
9 additional biomass made each day by the process, that is,
10 the growth portion of the biomass once the facility 1 has
11 achieved steady state conditions, so as to continue to
12 operate under such steady state conditions.

13 The recycled biomass in the flow stream 46 is directed
14 under flow from the pump 47 to a pre-anoxic region 50. The
15 pre-anoxic region 50 has no added oxygen and is positioned
16 and operated in such a manner as to remove nitrates that are
17 in the biomass by known processes. The biomass flows from
18 the pre-anoxic region 50 through a conduit or flow channel
19 51 to the first anaerobic region 10 to be mixed with the
20 influent waste water. A return line 52 flows some mixed
21 liquor from the first anaerobic region 10 to the pre-anoxic
22 region 50.

23 It is foreseen under the scope of the invention that a

fraction of the influent wastewater may be directed directly to the second anaerobic region or may be mixed with the slip stream from the first anaerobic region to the second anaerobic region. Preferably, the fraction of wastewater directed to the second anaerobic region without passing through the first anaerobic region would be less than about 10 percent of the total influent wastewater flow. the mixture of flows to the second anaerobic region in this manner may be utilized to control the detention time in the second anaerobic region so as to improve volatile short chain fatty acid production. the addition of influent waste water to the second anaerobic region without passing through the first anaerobic region assists in elutriating the volatile short chain fatty acids from the second anaerobic region in this manner, while not decreasing the solids retention time.

17 The following example is provided for the purpose of
18 demonstrating the invention and is not intended to limit the
19 scope of the invention or the claims of this application.

Example

21 A pilot facility was constructed in accordance with the
22 layout shown in Fig. 1 which was utilized to treat
23 wastewater. The facility was operated sequentially in a

1 first mode and thereafter in a second mode.

2 In both modes of operations, the influent flow rate was
3 50 cubic meters of waste water per day. Further, an average
4 the flow in channel 20 was 75 cubic meters per day, the flow
5 in channel 23 was 175 cubic meters per day, the flow in
6 channel 35 was 75 cubic meters per day, the flow in recycle
7 channel 33 was 100 cubic meters per day, the flow in
8 effluent channel 40 was approximately 50 cubic meters per
9 day, the flow in recycle sludge channel 46 was 25 cubic
10 meters per day, the flow in channel 51 was 40 cubic meters
11 per day and the flow in channel 52 was 15 cubic meters per
12 day.

13 The pilot facility was operated in mode 1 for one year.
14 In mode 1, all flow to the second anaerobic region 12 and
15 through channels 14 and 16 was prevented by effectively
16 removing region 12 from the facility by blocking channels 14
17 and 16.

18 The typical influent COD (amount of organic and oxygen
19 using matter measured as chemical oxygen demand) was
20 approximately 300 milligrams per liter and the influent had
21 a particulate and colloidal fraction of approximately 60%.
22 The first anaerobic region 10 had a volume of 2.07 cubic
23 meters. The mixed liquor in the first anaerobic region 10

1 had mixed liquid solids averaging approximately 3000
2 milligrams per liter and the total mass of COD entering the
3 first anaerobic region 10 with the influent wastewater
4 averaged approximately 9 kilograms per day. The phosphorus
5 entering with the influent wastewater averaged approximately
6 4 milligrams per liter. The average mass of solids in the
7 first anaerobic region 10 at any time was approximately 2.07
8 kilograms.

9 During the year of operation in the first mode, the
10 facility experienced a non rainy season and a rainy season.
11 During the rainy season, the concentrations of non water
12 components in the wastewater were highly diluted due to
13 large amounts of rain water. During the non rainy season,
14 the phosphorus content in the effluent clarified water was
15 approximately 0.5 milligrams per liter following an influent
16 phosphorus concentration of about 4 milligrams per liter.
17 However, acetate was required as a chemical addition in the
18 amount of between 5 and 10 milligrams per liter of influent
19 wastewater in order to obtain such reduction in phosphorus
20 level.

21 Subsequent to operation in the first mode, the facility
22 was operated in the second mode. In the second mode, the
23 second anaerobic region 12 (anpref region) was flow

1 connected to the facility and flow was allowed through
2 channels 14 and 16. The second anaerobic region had a
3 volume of 3 cubic meters. Flow from the first anaerobic
4 region 10 to the second anaerobic region 12 (and back) was
5 1.5 cubic meters per day and the daily transfer of solids
6 from the first anaerobic region 10 to the second anaerobic
7 region 12 averaged approximately 4.5 kilograms per day.
8 Approximately 0.27 kilograms of COD was absorbed by the
9 biomass in the second anaerobic region 12 each day. The
10 mass of the solids in the second anaerobic region 12
11 averaged approximately 75 kilograms at any time.

12 The ratio by weight of volatile suspended solids (VSS)
13 to total suspended solids (TSS) in the mixed liquor in the
14 first anaerobic region 10 and as transferred to the region
15 12 averaged approximately 0.78. While in the second
16 anaerobic region 12, approximately 25 percent of the VSS was
17 fermented by the biomass to volatile organic acids. The
18 ratio of the VSS to COD in the biomass in the second
19 anaerobic region 12 averaged approximately 1.42 by weight.
20 As noted before, the flow rate through the second anaerobic
21 region 12 was approximately 1.5 cubic meters per day. The
22 average daily production of volatile organic acids produced
23 by fermentation in the second anaerobic region 12 averaged

1 approximately 0.8775 kilograms per day and approximately
2 0.24 kilograms per day of volatile organic acids were
3 produced in the first anaerobic region 10 for a total of
4 about 1.1475 kilograms per day of short chain fatty acids
5 entering the first anaerobic region 10 from all sources.

6 For a process of this type it is calculated that
7 volatile organic or fatty acids in an amount approximately 4
8 times the mass of influent phosphorus is required in order
9 to provide a high degree of phosphorus removal in accordance
10 with the present invention. Total influent phosphorus level
11 (phosphorus in the influent wastewater) at the time of
12 operation of the second mode averaged approximately 0.25
13 kilograms per day which in theory required approximately
14 1.00 kilograms per day of volatile organic acids in the
15 first anaerobic region 10 to complete the biological
16 phosphorus process and which was calculated to be exceeded
17 during operation. During operation under the second mode
18 the soluble phosphorus level in the effluent averaged
19 approximately 0.03 milligrams per liter of clarified water
20 with a total removal efficiency averaging between 80 and 97%
21 during the year period of operation. During the rainy
22 portion of operation under the second mode, it was difficult
23 to maintain sufficient COD and phosphorus to demonstrate

1 effectiveness and for part of the rainy period, additional
2 amounts of each were added to allow continued study. During
3 operation in the second mode, no acetate had to be added to
4 effect substantial phosphorus removal.

5 It is to be understood that while certain forms of the
6 present invention have been illustrated and described
7 herein, it is not to be limited to the specific forms or
8 arrangement of parts described and shown.

9